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Technical Report S-147

# SAFETY CONSIDERATIONS IN THE DEVELOPMENT AND EXPLOSIVE CHARACTERIZATION OF NOVEL PROPELLANTS(U)

by

J. W. Parrott
T. H. Pratt

August 1967

U. S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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DAAH01-67-C-0947
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DA-01-021 AMC-11536(Z)
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ROHM AND HAAS COMPANY
REDSTONE RESEARCH LABORATORIES
HUNTSVILLE, ALABAMA 35807

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## FOREWORD

This work was performed under Contract DAAH01-67-C-0655 for exploratory development of propellants for missiles and rockets under cognizance of the Solid Propellant Chemistry Branch, Army Propulsion Laboratory and Center, Research and Development Directorate, U. S. Army Missile Command.

The data reported in the appendices were obtained mainly in support of the above contract; however, these data also include work performed under Contracts DAAH01-67-C-0947, DAAH01-67-C-0865 (ARPA Order 545), DA-01-021 AMC-11536(Z), and DA-01-021 AMC-13864(Z) under the cognizance of the Army Propulsion Laboratory and Center, Research and Development Directorate, U. S. Army Missile Command.

## (U) ABSTRACT

The general subject of development and evaluation of explosive experimental materials is discussed with emphasis on scale-up from bench synthesis to pilot-plant development. Topics include the criteria for selection of materials to scale up, the degree of remote operations required at various stages of development, the interpretation of sensitivity test data and handling experience, and the design of processes and handling procedures to minimize hazardous situations. The sensitivity testing program as it has been applied to the entire pilot-plant process for the manufacture of RH-SE-103A is presented, and data are given for 17 NF and 8 reference materials. A compendium of recent sensitivity data for novel and reference materials is presented in the appendices.

CONTENTS

## Section I. (U) INTRODUCTION

One of the major considerations in the development of high-energy compounds is the hazard to the personnel and equipment involved. This report will discuss some of the safety aspects the Redstone Research Laboratories of Rohm and Haas Company consider in the development of hazardous materials from laboratory synthesis to pilot-plant production with emphasis on the way in which safety considerations vary according to the quantity of material in process. Recent experience in the development of NF chemicals and propellants is used as an illustrative case of explosive hazards; toxic and corrosive hazards are not included. With this view, the two most important safety aspects of a program for the manufacture of novel propellants are selection of the chemical constituents and design of the process for safe operation. Handling experience and sensitivity test results are used as input data for such a constituent selection and subsequent process design. By the time a pilot-plant process becomes a matter of routine, the data from a sensitivity testing program should be used to seek out sources of explosive hazards.

## Section II. (C) SELECTION OF COMPOUNDS(U)

(U) The most important phase in the selection of compounds is the very beginning where extremely strict selection rules might preclude examination of compounds with potential advantages. On the other hand, some selectivity must be exercised. For instance, unrealistic impulse goals have, so far, impeded the development of safe, practical propellants. When a compound is selected for development, the selection rules become more and more strict as quantities in process become larger and non-remote processing becomes necessary.

(U) In the initial selection, the potential advantage of a compound prompts its synthesis and an examination of its properties. In the case of high-impulse propellants, the specific impulse can be calculated from its molecular structure in advance, but the sensitivity of a candidate compound cannot be reliably predicted - especially if a new class of chemical structure is involved.

(U) After a compound has been synthesized, there begins an interplay of factors which are weighed against the potential advantages of the compound, and from the relative weight given to these factors feasibility of producing the compound in larger quantities is decided. For a solid-propellant application these factors include, but are not restricted to, projected cost, ballistic performance, mechanical properties, handling hazards, thermal stability, and compatibility. In regard to safety in the manufacture of novel compounds, handling hazards are the most important consideration, but thermal stability and compatibility must be considered.

(U) For purposes of the present discussion, the development of a compound is broken down into four stages: synthesis, process research, process development, and routine pilot-plant production. This breakdown is somewhat arbitrary, since there is a large amount of communication and overlapping effort between the groups responsible for these respective stages. As a compound proceeds through these stages of development, handling experience is accumulated, sensitivity data become available, and the selection rules become more strict as the quantity of material increases.

(U) It is necessary that the laboratory-synthesis stage be remote since there are no safety data available on a novel compound except what may be inferred from similar compounds or similar classes of compounds. Since remote operations for this stage are relatively simple, the synthesis of any compound which offers a potential advantage can be attempted even though safety data are non-existent.

(C) Before the process-research stage is begun, a differential thermal analysis (DTA) and an impact-sensitivity value are obtained from the meagre supply of material produced in the laboratory synthesis. The handling experience obtained in the synthesis is also used as an important selection rule. For example, perfluoroguanidine (PFG) and its derivatives were not considered for process research because of the high frequency of explosions in the manufacture of PFG and the treacherous nature (1) of its derivatives. On the basis of the handling experience encountered during the synthesis stage, this class of compound was not scaled up.

(C) Selection of a compound for process research is then made on the basis of handling experience, DTA, and impact sensitivity. During the process-research stage preliminary batches of propellant are made for ballistic evaluation in micro-motors (2) and for a small-scale card-gap determination (3); in so doing, valuable handling experience is obtained in remote facilities. As the process research proceeds, the feasibility of continuing the scale up can be projected. It was at this stage the decision was made not to scale up the plasticizer OPE. A ballistic evaluation (4) showed that the advantages of the OPE-plasticized propellant of high specific impulse, $I_{sps} = 260.9$, and high burning rate, 3.3 in/sec at 1000 psia, were offset by the disadvantages of a high pressure exponent, 0.9, and a high temperature sensitivity, $\pi_K = 0.36\%/F^\circ$. Furthermore, the production of OPE would involve a complicated (3) and therefore expensive synthesis. An extensive hazards evaluation[1] of OPE and OPE propellants was therefore not carried out.

(U) It is during the process-development stage that an acceptable formulation becomes available in pound quantities. It is here that a hazards evaluation program is emphasized since any further scale-up of a material cannot feasibly be done completely by remote control. The sensitivity tests performed at these Laboratories in such a hazards program are given in Table I; the tests are listed approximately in the order in which they have been performed. These data are continually supplemented by the experience gained in manufacture and handling of the materials. It is during this phase of testing that the character of the compound emerges and one begins to get a feeling for the handling hazards involved. At this point, a judgment can be made as to the

[1]See reference (1) p. 169 for compilation of sensitivity data obtained at other laboratories.

conditions under which non-remote or semi-remote handling can be permitted-for instance, in obtaining mechanical property or thermal-stability data.

| Table I. (U) Sensitivity Tests | | | |
|---|---|---|---|
| | Quantity Required[a] | | |
| Sensitivity Test | Per Test | Per Set of Tests | References |
| Differential Thermal Analysis | 10-20 mg | 50 mg | 5 |
| Picatinny Impact | 10-20 mg | 0.2-0.4 gm | 3 |
| Card Gap (small-scale) | 8 ml | 50-80 ml | 3 |
| Failure Diameter | 1-160 ml | 2-400 ml | 3 |
| Ignition | 30 ml | 60-120 ml | 3 |
| O-M Impact | 0.03 ml | 0.75 ml | 3, 6 |
| Esso Friction | 50-100 mg | 0.5 gm | 3, 7 |
| Thiokol Friction | 0.02 ml | 0.2 ml | 8 |
| Thiokol Electrostatic | 10-20 mg | 0.1 g | 8 |
| Bottle Drop | 20 ml | 80 ml | 3 |
| Adiabatic Calorimeter | 15 ml | 30 ml | 3, 9 |
| Heat of Explosion | 0.5 g | 1 g | 3, 10 |
| Lead Column | 240 ml | 240 ml | 3, 11 |
| Card Gap (large-scale) | 160 ml | 2000 ml | 3, 11 |

[a]Quantities given in ml where the test specifies a volume of sample.

(U) By the time the pilot-plant development becomes a fairly routine production practice, all of the applicable sensitivity tests listed in Table I should have been performed on the process streams. These data, together with the handling experience, can be evaluated to decide if a compound is ready for pilot-plant production. The person responsible for the production of a material must "wear his belt and suspenders both". It cannot be assumed from incident-free handling experience, nor can it be assumed from "good sensitivity data," that a process can be scaled up. The process must be examined step by step in view of all the sensitivity data and handling experience; then any special tests that seem relevant should be performed. For example, a special bottle-drop test was performed (3) on neat TVOPA in which a stoppered 1-pint bottle containing 0.2 pint of TVOPA contained in a rubber lined carrier was dropped 54 successive ~~times~~ without incident before manual transportation in an identical configuration was permitted.[2] After such special tests have been performed, the process must be re-examined and designed around areas of potential hazard. Since the handling experience is not quantitative and the sensitivity tests do not necessarily correspond to stimuli encountered in the manufacture of the material, the decision on further scale-up must involve a certain amount of subjective judgment.

(U) For example, 1,2 DP would not at this time be acceptable for pilot-plant production even though significant quantities have been made and shipped to other laboratories.[3] Thus far, 1,2 DP has been manufactured in the vapor phase where a high frequency of explosions have occurred. If a need for large quantities of 1,2 DP should arise, it would be necessary to design equipment capable of safely handling low-boiling-point olefins.

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[2]At the time these tests were performed, it was thought that neat TVOPA would have to be transported. Later, the process was modified so that neat TVOPA was not isolated.

[3]See reference 1, p. 106, for compilation of sensitivity data for this compound obtained at other laboratories.

## Section III. (C) PROCESS DESIGN(U)

(C) An example of a process designed to minimize hazards is the practice of keeping NFPA and TVOPA in solution during reaction and storage. The use of solvent is probably the easiest and surest way of "desensitizing" an explosive material. By keeping NFPA and TVOPA in solution wherever possible, the initiation and propagation of an explosion are minimized. This is shown by the results of the sensitivity tests listed in Table I where all of the applicable tests gave a negative result for the NFPA and TVOPA solutions. Even though initiation is minimized by the addition of solvent, explosions have occurred in the liquid-phase flow reactor (12) where the $N_2F_4$-olefin reaction takes place. The $N_2F_4$ and the olefin are put into solution separately under high pressure. These solutions are remotely mixed into a 0.18-in.-diameter tube at high temperature and pressure; the reaction proceeds as the mixture flows through the tube. When explosions have occurred, they did not propagate back into the $N_2F_4$ feed or into the product. Thus, propagation was minimized by the use of solvent. [Since the quantity of explosives in the reactor was small, the explosions resulted in a shutdown of only a few hours.]

(C) Another advantage of manipulating substances in dilute solution is that the solvent can act as a heat sink for an exothermic reaction. This principle is made use of in the copolymerization of NFPA with acrylic acid (AA) where the ethyl acetate solvent acts as an energy sink for the heat of polymerization. If the copolymerization were attempted with undiluted NFPA and acrylic acid, an explosion of the whole batch would most probably occur.

(U) Hazards can also be minimized by using a contuous rather than a batch process. The amount of material present during the time an energy souce is available is restricted to smaller quantities in a continuous process. This is a consideration in the distillation of NFPA as well as in the liquid-phase flow reaction already mentioned. The NFPA distillation is carried out in a wiped-film evaporator (rather thar a still) in which only 1-2% of an NFPA batch is at the boiling point at any one time.

(C) Deviations from these principles can lead to hazardous situations; for example, an incident occurred (Figure 1) involving 25 lbm of neat NFPOH which is the transesterification intermediate between NFPF and NFPA. An investigation of this incident revealed that the explosion was caused by an adiabatic thermal decomposition of neat NFPOH. Furthermore, the thermal decomposition was promoted

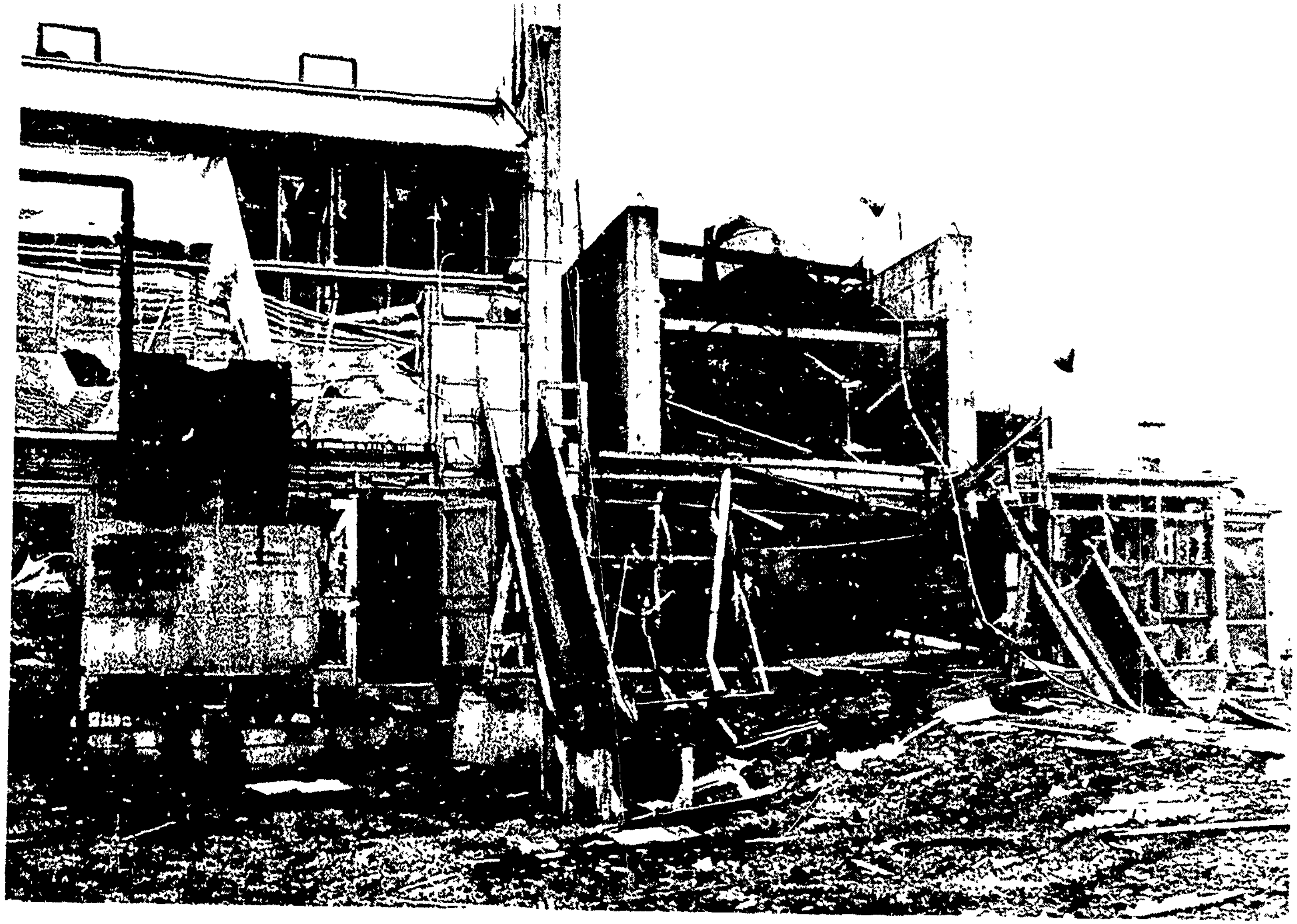

FIGURE 1. (U) NFPOH REACTOR INCIDENT.

by zinc chloride which was present as a catalyst for the subsequent acrylation step. The zinc chloride was charged to the kettle along with the NFPF and was therefore present after the solvent had been removed from the NFPOH. After the explosion occurred, it was found by differential thermal analysis that zinc chloride enchanced the thermal decomposition of NFPOH to the extent that exothermic chemical reactions would occur in the region of 30° C. The transesterification procedure has since been modified such that the NFPOH is kept in ethylene dichloride at a maximum NFPOH concentration of 50%.

(C) In the manufacture of solid propellant, it is necessary to remove the solvent somewhere in the process stream. In the case of the RH-SE- series of propellants, the ingredients are kept in solution until the work-up of the binder, a solution of NFPA-AA copolymer in TVOPA. The stripping operation is performed after mixing the copolymer solution and the TVOPA solution in their proper proportion. There are primary advantages of this process scheme over that of stripping the TVOPA and the copolymer solutions separately. The neat copolymer is too viscous to be manipulated conveniently and the neat TVOPA is too sensitive to allow non-remote handling. On the other hand, the neat binder is less viscous than the copolymer and less sensitive than the TVOPA. Thus, the TVOPA is used to reduce the viscosity of the copolymer, and the copolymer is used to decrease the sensitivity of the TVOPA (Table II).

Table II. (C) Viscosity and Sensitivity Data for RH-SE-103 Propellant Constituents(U)

| | Copolymer NFPA/AA=95/5 | TVOPA (neat) | TP-11 Binder TVOPA/Copolymer=2/1 |
|---|---|---|---|
| Viscosity, cP | $>10^5$ | --- | 4000 |
| DTA[a] | 241° | 263° | 235° |
| Picatinny impact[b] | >38 | 8 | 10 |
| Small-scale Card gap[c] | d | 1.01 | 0.45 |
| Ignition[e] | d | E/- | B/B |
| Bottle drop[f] | d | N/N/E | N/N/N |

[a]Differential thermal analysis peak exotherm in C° at a heating rate of 10° C/min. Ref. 5.

[b]Modified Picatinny Impact height in kg-in., one kg weight, RDX > 10.5 kg-in.

[c]Small-scale card-gap thickness in inches, Ref. 3.

[d]The viscosity of the copolymer precludes the performance of these tests.

[e]Reported as result with immersed Atlas match/result with immersed M1A1 squib, 30 ml sample, E=Explode, B=Burn, Ref. 3.

[f]Reported as result in the drop series—five successive drops of a 25-ml sample contained in a 120-ml polyethylene bottle/five similar drops with approximately 50 $\frac{1}{8}$-in.-diameter glass beads added/one drop of a 25-ml sample contained in a 38-ml glass vial. All drops from 115-inches onto a steel plate, E=Explode, N=No Reaction, Ref. 3.

## Section IV. (C) SENSITIVITY TESTING(U)

(C) A specific propellant formulation, RH-SE-103A, was selected at these Laboratories for scale-up to 300-lbm batches, Table III.

Table III. (C) RH-SE-103A Propellant Formulation(U)

| | | Wt. % |
|---|---|---|
| NFPA-AA (95/5) | RH-TP-11 | 13.0 |
| TVOPA | RH-TP-11 | 26.0 |
| AP, 55μ, 1% Alon®[a] C | | 46.0 |
| Al, Alcoa 140 | | 15.0 |
| Unox®[b] 221 | Added as grams per 100 grams propellant | 1.51[c] |
| FeAA | Added as grams per 100 grams propellant | 0.075 |

[a] Trademark of Cabot Corporation, Boston, Mass.
[b] Trademark of Union Carbide Corporation, New York, N.Y.
[c] This number may be varied slightly depending on the assay of the Unox 221 lot being used.

(C) The manufacture of this propellant began with the fluorination of urea and was carried through several subsequent reaction steps in the manufacture of the TP-11 binder indicated in Table III. A flow chart of the chemical intermediates as well as propellant manufacture is shown in Figure 2. This process has been subjected to an extensive program of sensitivity testing for potential sources of explosive hazard, whether owing to the intrinsic properties of the substance, to physical state or environment, or to manipulations and stimuli to which the substances are subjected. The production of $N_2F_4$, the difluoramination of olefins, the manufacture of NFPA, the preparation of acrylic acid copolymer, and propellant mixing and casting have all been analyzed. In some cases, such as reacting systems, direct tests could not be performed and hazards have been inferred from properties of reactants or products.

(U) The test methods employed in this program are given in Table I; however, since most substances are not amenable to all test methods, only those of potential significance have been performed. Considerable experience in the manufacture of plastisol nitrocellulose composite propellants had been obtained at these Laboratories before the effort of NF scale-up was attempted. Therefore, the sensitivity data for plastisol propellants and propellant constituents were used as

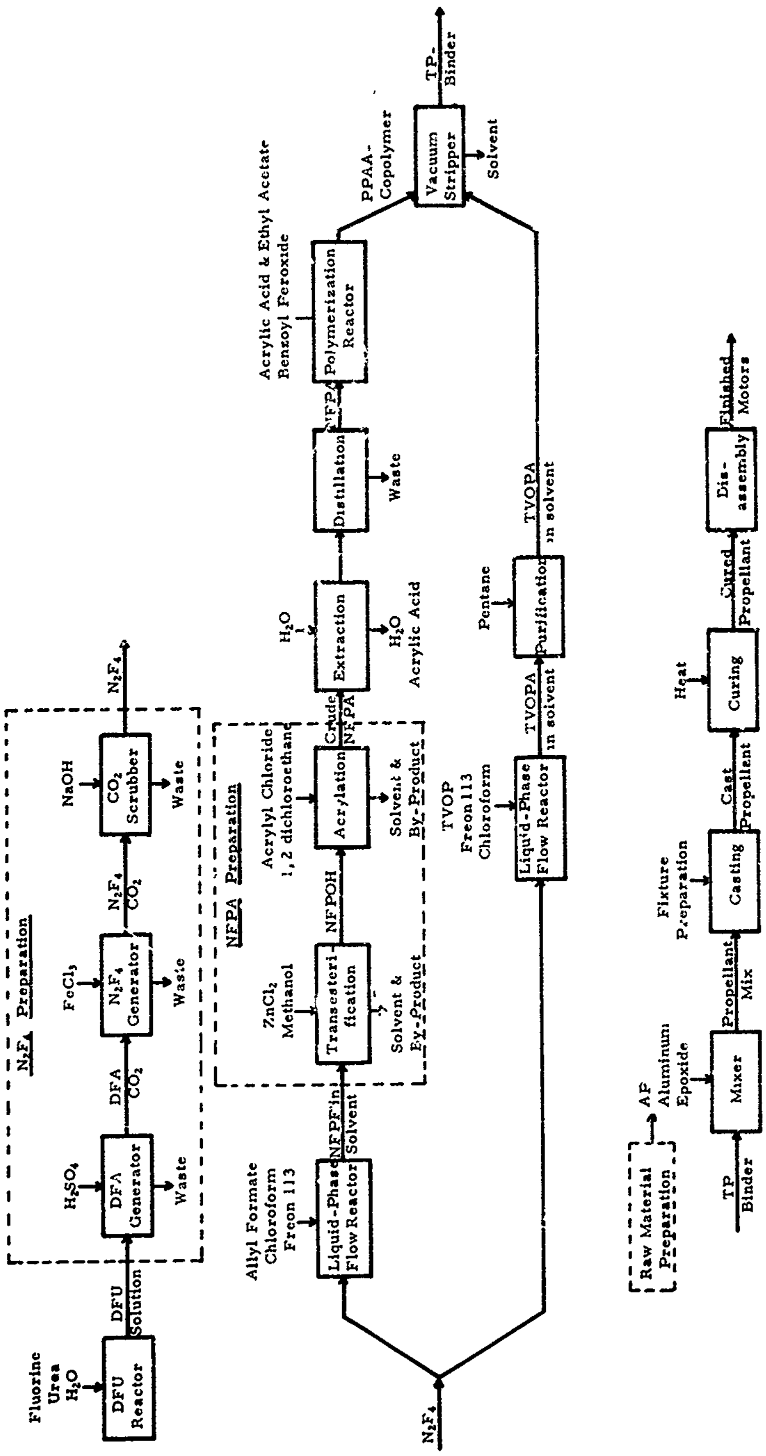


FIGURE 2. (C) FLOW CHART FOR MANUFACTURE OF RH-SE-103A PROPELLANT (U).

a datum line in the hazards evaluation program of the NF prototype propellant. The data for both processes are summarized in Table IV. In view of the data obtained, we are confident that NF plasticizers and binders can be manufactured with present explosives technology in conventional equipment. No new hazards (in kind or degree) have been encountered in the production of the chosen NF-propellant or minor variations thereof as compared with our experience in producing other reactive binder propellants.

(U) At these Laboratories sensitivity testing is a continuing effort, in that sensitivity data are obtained as novel materials become available; this is true for NF as well as for non-NF substances. An up-to-date compendium of recent sensitivity data has been included as Appendices to this report. These data, which are exhaustive for some tests, are reported without comment.

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Table IV. (C) Test Results (U)

| | Card[a] Gap | Failure[b] Diam. | Picatinny[c] Impact | O-M Impact[d] | Esso[e] Friction | Ignition[f] | Lead[g] Column | Bottle[h] Drop | DTA[i] | Adiabatic[j] Calorimeter | Heat of[k] Explosion |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NFPF | 0.73 | <0.27 | 26.2 | 7.69 | >9 | B/B | 1.1 | N/N/N | 195 | X[m] | 927 |
| NFPOH[n] | 1.26[n] | <0.27[n] | | | >9 | E/E[n] | 1.7[n] | | | $>10^{-4}$ | |
| NFPA | 0.91 | <0.27 | >38 | 7.0 | >9 | N/N | 0.3 | N/N/N | 227 | X | 867 |
| PPAA-3 | | >0.44 | 21.0 | X | >9 | | | | 241 | | |
| TVOPA | 1.01 | <0.27 | 8.09 | 5.88 | >9 | E/ | p | N/N/E | 263 | $2.2 \times 10^{-3}$ | 1368 |
| TP-11 | 0.45 | <0.27 | 10.1 | X | >9 | B/B | 0.4 | N/N/N | 235 | $4.6 \times 10^{-3}$ | 1123 |
| TP-11 + Al | 1.27 | <0.27 | 6.84 | X | >9 | B/B | 1.6 | X | 247 | | 2077 |
| TP-11 + APC | 1.23 | <0.27 | 7.87 | X | >9 | B/B | 1.2 | X | 253 | | 1415 |
| TP-11 + Al + APC | 1.27 | <0.27 | 5.87 | X | 5-9 | B/B | 1.7 | X | 254 | | 1701 |
| RH-SE-103A Slurry | 1.22 | <0.27 | 6.47 | X | 5-9 | B/B | 1.7 | X | 243 | $2.1 \times 10^{-3}$ | 1632 |
| RH-SE-103A | 1.20 | <0.27 | 8.09 | X | >9 | X | 1.4[q] | X | 233 | $2.3 \times 10^{-3}$ | 1683 |
| TVOPA/Solvent = 15/85 | X | >1.44 | >38 | >120 | | N/N | | | X | X | |
| NFPF/Solvent = 23/77 | X | >1.44 | >38 | >120 | | N/N | 0 | N/N/N | X | X | |
| NFPOH/Solvent = 50/50 | 0.71[r] | 0.62 | >38 | >120 | | N/N | 0 | | X | X | |
| NFPA/AA/Solvent = 15.2/0.8/84 | X | >1.44 | >38 | >120 | >9 | N/N | 0 | N/N/N | X | X | |
| PPAA-3/Solvent = 16/84 | X | >1.44 | >38 | >120 | >9 | N/N | 0 | N/N/N | X | X | |
| TVOPA/PPAA-3/Solvent = 9/4.5/86.5 | X | >1.44 | >38 | >120 | >9 | N/N | 0 | N/N/N | X | X | |
| NG | 0.91 | <0.48 | 7.86 | X | >9 | N/ | | | 204 | | 1563 |
| NG/EG | 0.51 | <0.48 | 24.8 | X | | | 0.8 | | | | |
| TMETN | 0.30 | 0.27 | 22.2 | | >9 | N/N | 0.7 | | | | |
| TEGDN | 0.19[r] | 1.05 | >38 | | | N/N | 0 | | 203 | | |
| RH-P-112cf Slurry | 1.51 | <0.27 | 7.2 | X | 5-9 | | | X | | | |
| RH-P-112cf | 0.77 | 0.36 | 6.7 | X | >9 | X | 0[q] | X | 173 | | |
| Double-Base Powder | 2.60[r] | | 10.6 | | | | 2.0 | | | | |
| AP (cf) | 1.70[r] | | 14.4 | | | | | | | | |

Footnotes for Table IV

[a] Card-gap thickness in inches, small-scale unless otherwise noted, Ref. 3 and 11.
[b] Steel confined failure diameter in inches, Ref. 3.
[c] Modified Picatinny Impact Height in kg-in., one kg weight, RDX = 10.5 kg-in. Ref. 3.
[d] Olin-Mathieson Impact Height in kg-cm., one kg weight, n-propyl nitrate = 13.5 kg-cm. Ref. 3.
[e] Moh's hardness of grit required to initiate sample, Ref. 7.
[f] Reported as result with an immersed Atlas match/result with an immersed M1A1 squib. E = explode, B = burn, N = no observable reaction, Ref. 3.
[g] Reported as column height reduction of a 1.5-in.-diam. by 4-in.-long lead column induced by an 8-oz. sample when initiated with a No. 8 detonator, Ref. 11.
[h] Reported as result in the drop series - five successive drops of a 25-cc sample contained in a 120-cc polyethylene bottle/five similar drops with approximately 50 $\frac{1}{8}$-in.-diam. glass beads added/one drop of a 25-cc sample contained in a 38-cc glass vial. All drops from a height of 115 in. onto a steel plate.
[i] Differential thermal analysis peak exotherm in C° at a heating rate of 10 C°/min, Ref. 5.
[j] Adiabatic calorimeter heating rate at 143°C in cal/gm sec, Ref. 9.
[k] Heat of explosion - $\Delta Ex$ in cal/gm, as determined in a Parr calorimeter under 1000 psig. of nitrogen, Ref. 10.
[m] Crosses denote tests which cannot be performed - blanks denote tests which have not been performed.
[n] NFPOH taken from process stream and stripped; Analysis: NFPOH/NFPF/Solvent = 77.5/5.4/17.2
[p] A TVOPA/Solvent solution of approximately 75% TVOPA gave a result of 0.7 in.
[q] Performed with a 2-in. cube of propellant and a J-2 detonator, Ref. 11.
[r] Large-scale card-gap test, Refs. 3 and 11.

## Section V. (U) SUMMARY AND CONCLUSIONS

In summary, the research on NF materials at Redstone Research Laboratories has been directed toward compounds having potential advantages which, at the outset, have had a reasonable probability of not having unmanageable sensitivity characteristics. Research on the derivatives of PFG was discontinued because of adverse behavior during laboratory synthesis. Process development of OPE was not initiated because of undesirable ballistic properties and complicated synthesis. Pilot-plant production of 1,2 DP is not feasible without more extensive process development. Propellant binders composed of NFPA and TVOPA are made routinely in pilot-plant production by keeping the explosive materials in solution and using continuous processes wherever possible. An extensive testing program was carried out to obtain sensitivity data on RH-SE-103A propellant and its NF-precursers. In view of these sensitivity data and the accumulated handling experience, we are confident that NF propellant binders used in making the RH-SE- propellant series offer no new hazards in kind or degree when compared with other reactive binder propellants.

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## APPENDIX A

## (C) SENSITIVITY DATA FOR NF MATERIALS(U)

(U) Published herewith are the sensitivity data which have been obtained since the publication of Rohm and Haas Company Special Report S-79 (3). These data were accumulated as a part of the hazards evaluation of NF materials.

| | |
|---|---|
| Table V | Card-Gap Sensitivity Test Results for NF Materials. (This table together with Table XIV is an exhaustive compilation of card-gap sensitivity data for internal entry numbers 480 to 619 inclusive. |
| Table VI | Failure-Diameter Test Results for NF Materials. (This table together with Table XV is an exhaustive compilation of failure-diameter data since the publication of Rohm and Haas Company Special Report S-67 (13) and contains all data for internal entry numbers 279 to 388 inclusive.) |
| Table VII | Differential-Thermal-Analysis Results for NF Materials. (This table together with Table XVI is a compilation of DTA data obtained in conjunction with other sensitivity data.) |
| Table VIII | Impact-Sensitivity Test Results for NF Materials. (This table together with Table XVII is a compilation of impact sensitivities obtained in conjunction with othe· sensitivity data.) |
| Table IX | Ignition Test Results for NF Materials. (This table together with Table XVIII is an exhaustive compilation of ignition-test data for internal entry numbers 16 to 72 inclusive.) |
| Table X | Friction-Sensitivity Test Results by Esso Friction Screw (7) for NF Materials. (This table together with Table XIX is an exhaustive compilation of all Esso Friction Screw obtained through internal entry number 37.) |
| Table XI | Friction-Sensitivity Test Results by Thiokol Rotating Cup (8) for NF Materials. (This table together with Table XX includes all friction tests performed for these Laboratories by Thiokol Chemical Corporation, Huntsville Division from the publication of Rohm and Haas Company Special Report S-79 to 1 July 1967.) |

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|---|---|
| Table XII | Lead-Column Test Results for NF Materials. (This table together with Table XXI is an exhaustive compilation of all lead-column test data through internal entry number 46.) |
| Table XIII | Bottle-Drop Tests for NF Materials. (This table is an exhaustive compilation of bottle-drop data obtained since the publication of Rohm and Haas Company Special Report S-79 (3). No bottle-drop tests have been performed on non-NF materials during this period.) |
| Figure 3 | Batch-Number Flow Sheet for RH-SE-103A Process Survey. |

Table V. (C) Card-Gap Sensitivity Test Results for NF Materials(U)

| Designation | Batch | Gap Thickness (in.) | Remarks |
|---|---|---|---|
| | | **Liquids** | |
| APA | | $0.37^{0/1}$-$0.46^{1/0}$ [a] | |
| NFPA | 117 | $0.90^{2/0}$-$0.92^{0/2}$ | |
| NFPF | 148 | $0.72^{2/0}$-$0.74^{0/2}$ | |
| TVOPA | 100-1N | $1.00^{2/1}$-$1.02^{0/2}$ | |
| NFPOH/Solvent | | $1.25^{2/0}$-$1.27^{1/2}$ | 77/23 |
| NFPOH/Solvent | | $0.70^{1/0}$-$0.73^{0/2}$ | 50/50 |
| TVOPA/Solvent | 100-75 | $0.68^{2/0}$-$0.70^{0/2}$ | 75/25 |
| TVOPA/Solvent | 100-66 | $0.78^{2/0}$-$0.80^{0/2}$ | Analyzed 77/23 |
| | | **Binders** | |
| TP-9 | 1001 | $0.62^{2/0}$-$0.64^{1/2}$ | TVOPA/[NFPA/ AA= 94/6]= 2/1 |
| TP-11 | 1003 | $0.44^{2/0}$-$0.46^{0/2}$ | TVOPA/[NFPA/ AA= 95/5 ] = 2/1 |
| TP-11 | 1003 | $0.84^{2/0}$-$0.86^{0/2}$ | 180°F |
| TP-14 | 1000 | $0.74^{2/1}$-$0.76^{0/2}$ | TVOPA/ [NFPA/ AA=95/5] =3/1 |
| TP-GNFPA | MB-669-48 | $0.52^{1/0}$-$0.60^{0/1}$ | TVOPA/[GNFPA/ AA= 95/5]= 2/1 |
| TU-105 | 7002 | $0.39^{2/0}$-$0.41^{0/2}$ | TVOPA/[EA/AA =95/5] =5/1 |
| P-BEP/TVOPA | | $1.14^{1/0}$-$1.21^{0/1}$ | 1/1 |

Table V. (Cont'd) (C) Card-Gap Sensitivity Test Results for NF Materials(U)

| Designation | Batch | Gap Thickness (in.) | Remarks |
|---|---|---|---|
| **Slurries** | | | |
| RH-SE-103cd | 1007 | $1.20^{1/0}$-$1.22^{1/2}$ | AP/Al/TP-9 = 46/15/39 |
| RH-SE-103cf | 1021 | $1.16^{2/0}$-$1.18^{0/3}$ | AP/Al/TP-9 = 46/15/39 |
| RH-SE-103cf | 1032 | $1.14^{3/0}$-$1.16^{0/3}$ | AP/Al/TP-9 = 46/15/39 |
| RH-SE-103cf | 1033 | $1.16^{3/0}$-$1.18^{0/3}$ | AP/Al/TP-9 = 46/15/39 |
| RH-SE-103af | 1034 | $1.14^{2/0}$-$1.16^{1/2}$ | AP/Al/TP-9 = 46/15/39 |
| RH-SE-103A | 1049 | $1.20^{2/0}$-$1.24^{0/2}$ | AP(af)/Al/TP-11 = 46/15/39 + 0.075 FeAA |
| RH-SE-195cf | 1000 | $0.90^{2/0}$-$0.92^{0/2}$ | AP/TP-9 = 58/42 |
| RH-SE-196cf | 1000 | $1.10^{2/0}$-$1.12^{1/2}$ | AP/Al/TP-9 = 44/14/42 |
| RH-SE-233 | 02 | $1.74^{1/0}$-$1.78^{0/1}$ | HMX(F)/TP-11 = 60/40 |
| RH-SE-233 | 1003 | $1.76^{2/0}$-$1.78^{0/2}$ | HMX(F)/TP-11 = 60/40 |
| RH-SE-234ci | 1001 | $1.18^{2/0}$-$1.20^{1/1}$ | AP/Al/TP-14 = 46/15/39 |
| RH-SE-240cc | 7001 | $1.56^{2/0}$-$1.58^{0/2}$ | AP/HMX(B)/Al/TP-12 = 20/39/1/40 |
| RH-U-105 | 7002 | $1.12^{2/0}$-$1.14^{0/2}$ | APC/Al/TU-105 = 46/15/39 |
| RH-Y-1af | 01 | $1.20^{2/0}$-$1.22^{0/2}$ | AP/Al/TP-GNFPA=46/15/39 |
| RH-Y-1af | 7001 | $1.20^{1/0}$-$1.22^{0/2}$ | AP/Al/TY-1 = 46/15/39 |
| TP-11/AP | -- | $1.22^{2/0}$-$1.24^{0/2}$ | 39/46, af-AP |
| TP-11/Al | -- | $1.26^{1/0}$-$1.28^{0/1}$ | 39/15 |
| TP-11/AP/Al | -- | $1.26^{2/1}$-$1.28^{0/2}$ | 39/46/15, af-AP |
| **Propellants** | | | |
| RH-SE-103cf | 1021 | $1.12^{2/0}$-$1.14^{0/2}$ | AP/Al/TP-9 = 46/15/39 |
| RH-SE-103cf | 1032 | $1.10^{2/0}$-$1.12^{1/3}$ | AP/Al/TP-9 = 46/15/39 |
| RH-SE-103cf | 1033 | $1.12^{2/0}$-$1.14^{0/2}$ | AP/Al/TP-9 = 46/15/39 |
| RH-SE-103af | 1034 | $1.16^{2/0}$-$1.18^{1/2}$ | AP/Al/TP-9 = 46/15/39 |
| RH-SE-103A | 1048 | $1.19^{2/0}$-$1.21^{1/0}$ | APaf/Al/TP-11 = 46/15/39+ 0.075 FeAA |
| RH-SE-103A | 1050 | $1.23^{2/0}$-$1.25^{0/2}$ | |
| RH-SE-103af | 1157 | $1.16^{1/0}$-$1.18^{0/1}$ | AP/Al/TP-12 = 46/15/39, 74°F |
| RH-SE-103af | 1157 | $1.24^{1/0}$-$1.26^{0/1}$ | 135°F |
| RH-SE-195cf | 1000 | $0.86^{2/1}$-$0.88^{0/2}$ | AP/TP-9 = 58/42 |
| RH-SE-196cf | 1000 | $1.12^{2/0}$-$1.14^{1/2}$ | AP/Al/TP-9 = 44/14/42 |

Table V. (Cont'd) (C) Card-Gap Sensitivity Test Results for NF Materials(U)

| Designation | Batch | Gap Thickness (in.) | Remarks |
|---|---|---|---|
| RH-SE-221 | -- | $1.80^{1/0}$-$2.00^{0/1}$ | HMX(E)/TP-11 = 80/20 |
| RH-SE-233 | .02 | $1.74^{2/0}$-$1.78^{1/1}$ | HMX(F)/TP-11 = 60/40 |
| RH-SE-233 | 1003 | $1.76^{2/0}$-$1.78^{0/2}$ | HMX(F)/TP-11 = 60/40 |
| RH-SE-234ci | 1001 | $1.18^{2/0}$-$1.20^{0/2}$ | AP/Al/TP-14 = 46/15/39 |
| RH-SE-240cc | 7001 | $1.60^{2/0}$-$1.62^{0/2}$ | AP/HMX(E)/Al/TP-12 = 29/39/1/40 |
| RH-SE-240ci | 7004 | $1.56^{2/0}$-$1.58^{0/2}$ | |
| RH-U-101af | 7001 | $1.10^{2/0}$-$1.12^{0/2}$ | AP/Al/TU-102 = 46/15/39 |
| RH-U-105af | 7002 | $1.15^{2/0}$-$1.17^{0/2}$ | AP/Al/TU-105 = 46/15/39 |
| RH-Y-1af | 02 | $1.18^{2/1}$-$1.20^{0/2}$ | AP/Al/TP-GNFPA=46/15/39 |
| RH-Y-1af | 7001 | $1.20^{2/1}$-$1.22^{0/2}$ | AP/Al/TY-1 = 46/15/39 |

Large Scale

| Designation | Batch | Gap Thickness (in.) | Remarks |
|---|---|---|---|
| RH-SE-103af | 1120 | $1.00^{2/0}$-$1.02^{1/2}$ | AP/Al/TP-11 = 46/15/39 |
| RH-SE-103af | 1157 | $1.08^{1/0}$-$1.10^{0/1}$ | AP/Al/TP-12 = 46/15/39, 74°F |
| RH-SE-103af | 1157 | $1.18^{1/0}$-$1.20^{0/1}$ | 135°F |

Tests performed with small-scale acceptors and Composition C-4 donors 2 in. diam. × 2 in., ρ = 1.59 gm/cc, hand packed

| Designation | Batch | Gap Thickness (in.) | Remarks |
|---|---|---|---|
| TY-1 | TP-12G-101 | $0.42^{2/0}$-$0.44^{0/2}$ | TVOPA/[ GNFPA/AA = 96/4 ] = 2 |
| RH-V-3cb | 03 | $0.90^{1/0}$-$0.92^{0/2}$ | AP/Al/TVOPA/[ BA/AA = 95/5]=46/15/30/9 |

[a] Superscripts give ratio of go/no go at indicated gap thickness. These sum to less than the total number of trials and indicate only the bounds of the 50% point.

Table VI. (C) Failure-Diameter Test Results for NF Materials(U)

Steel Confined

| Designation | Batch | $D_f$, in. | Remarks |
|---|---|---|---|
| | | Liquids | |
| NFPA | 117 | <0.27 | |
| TVOPA | 100-IN | <0.27 | |
| NFPF | 148 | <0.27 | |
| NFPA/AA/Solvent | -- | >1.05 | 15.2/0.8/84 |
| NFPA/AA/Solvent | 117S | >1.44 | 15.2/0.8/84 |
| TVOPA/Solvent | 100-75 | <0.27 | 75/25 |
| TVOPA/Solvent | 100-66 | <0.27 | 66/33 |
| TVOPA/Solvent | 121+122 | >1.44 | 11/89 |
| NFPOH/Solvent | -- | <0.27 | 77/23 |
| NFPOH/Solvent | -- | 0.62-0.82 | 50/50 |
| NFPF/Solvent | 371-1 | >1.44 | 22/78 |
| PPAA-3/Solvent | 1001 | >1.44 | 16/84 |
| TP-11/Solvent | 1003CS | >1.44 | 14/86 |
| PPAA-5/Solvent | 105 | >0.48 | 39/61 |
| PPAA-3 | MB-669-33 | >0.50 | gumstock, glass confined |
| PPAA-3 | 1001N | >0.48 | gumstock, steel confined |
| | | Binders | |
| TP-11 | 1003 | <0.27 | TVOPA/[NFPA/AA= 95/5] = 2/1 |
| TP-14 | 1000 | <0.27 | TVOPA/[NFPA/AA = 95/5] = 3/1 |
| TP-GNFPA | MB-669-48 | 0.27-0.36 | TVOPA/[GNFPA/AA = 95/5] = 2/1 |
| P-BEP/TVOPA | | <0.27 | P-BEP/TVOPA = 1/1 |
| | | Slurries | |
| TP-11/AP | | <0.27 | 39/46, no curing agent |
| TP-11/Al | | <0.27 | 39/15, no curing agent |
| TP-11/AP/Al | | <0.27 | 39/46/15, no curing agent |
| RH-SE-103A | 1049 | <0.27 | APaf/Al/TP-11 = 46/15/39 + 0.075 FeAA |

Table VI. (Cont'd) (C) Failure Diameter Test Results for NF Materials(U)

| Designation | Batch | $D_f$, in. | Remarks |
|---|---|---|---|
| RH-SE-234ci | 1001 | <0.27 | AP/Al/TP-14 = 46/15/39 |
| RH-Y-laf | 01 | <0.27 | AP/Al/TG-GNFPA = 46/15/39 |
| | | Propellants | |
| RH-SE-103A | 1048 | <0.27 | AP(af)/Al/TP-11 = 46/15/39 + 0.075 FeAA |
| RH-SE-103A | 1050 | <0.27 | ... |
| RH-SE-233 | 02 | <0.27 | HMX(F)/TP-11 = 60/40 |
| RH-SE-234ci | 1001 | <0.27 | AP/Al/TP-14=46/15/39 |
| RH-Y-laf | 02 | <0.27 | AP/Al/TP-GNFPA = 46/15/39 |

Table VII. (C) Differential-Thermal-Analysis Results for NF Materials(U)

| Designation | Batch | Exotherm, °C Beginning | Peak | Remarks |
|---|---|---|---|---|
| NFPA | 117 | | 227 | Preceded by polymerization exotherm |
| NFPF | 148 | 178 | 195 | |
| NFPOH | | | 173 | Small exotherms at 94° and 140° |
| PPAA-3 | 1001 | 197 | 241 | Endotherm at 87° |
| TP-11 | 1003 | 177 | 235 | |
| TVOPA | 100-1 | 177 | 263 | Small exotherm at 104° |
| TP-11/AP | | 197 | 253 | |
| TP-11/Al | | 186 | 247 | |
| TP-11/AP/Al | | 202 | 254 | |
| RH-SE-103A | 1049 | 184 | 243 | Slurry |
| RH-SE-103A | 1050 | | 233 | Cured |
| RH-SE-103af | 1159 | | 248 | AP/Al/TP-19=46/15/39 |
| RH-SE-246cc | 7006 | | 228 | AP/HMX(B)/TP-11 = 20/40/40 |
| RH-U-101af | 7001 | | 249 | AP/Al/TU-102=46/15/39 |
| RH-Y-laf | 7001 | | 255 | AP/Al/TY-1=46/15/39 |

Table VIII. (C) Impact-Sensitivity Test Results for NF Materials(U)

| Designation | Batch | Picatinny Kg-in. | Olin-Mathieson Kg-cm | Remarks |
|---|---|---|---|---|
| | | Liquids | | |
| APA | | >38 | 15.5 | |
| NFPA | | >38 | 7.0 | |
| NFPF | 148 | 26.2 | 7.69 | |
| TVOPA | 100-IN | 8.09 | 5.88 | |
| NFPA/AA/Solvent | 117S | >38 | >120 | 15.2/0.8/84 |
| NFPF/Solvent | 371-1 | >38 | >120 | 23/77 |
| NFPOH/Solvent | | 12.0 | 4.0 | 77/23 |
| NFPOH/Solvent | | >38 | >120 | 50/50 |
| TVOPA/Solvent | 100-75-2 | 17.2 | 6.67 | 75/25 |
| TVOPA/Solvent | 100-66 | 9.31 | | 66/33 |
| TVOPA/Solvent | 100-50 | >38 | 9.0 | 50/50 |
| TVOPA/Solvent | 100-25 | >38 | >120 | 25/75 |
| TVOPA/Solvent | 100-15 | >38 | >120 | 15/85 |
| TP-11/Solvent | 1003CS | >38 | >120 | 14/86 |
| PPAA-3/Solvent | 1001 | >38 | >120 | 16/84 |
| PPAA-3 | 1001N | 21.0 | | Gumstock |
| | | Binders | | |
| TP-11 | 1003 | 10.1 | | |
| | | Slurries | | |
| TP-11/AP | | 7.87 | | |
| TP-11/Al | | 6.84 | | |
| TP-11/AP/Al | | 5.87 | | |
| RH-SE-103A | 1049 | 6.47 | | |
| | | Propellants | | |
| RH-SE-103A | 1050 | 8.09 | | AP/Al/TP-11=46/15/39 |
| RH-SE-103af | 1152 | 6.94 | | AP/Al/TP-19=46/15/39 |
| RH-SE-233 | 1003 | 8.9 | | HMX(F)/TP-11 = 60/40 |

Table VIII. (Cont'd.) (C) Impact-Sensitivity Test Results for NF Materials(U)

| Designation | Batch | Picatinny Kg-in. | Olin-Mathieson Kg-cm. | Remarks |
|---|---|---|---|---|
| RH-SE-239 | 7002 | 10.6 | | HMX(B)/Al/TP-11/=59/1/40 |
| RH-SE-240cc | 7001 | 6.7 | | AP/HMX(B)/Al/TP-11=20/39/1/40 |
| RH-SE-240ci | 7002 | 5.1 | | |
| RH-SE-246cc | 7006 | 6.2 | | AP/HMX(B)/TP-11 = 20/40/40 |
| RH-U-101af | 7001 | 5.1 | | AP/Al/TU-102= 46/15/39 |

Table IX. (C) Ignition-Test Results for NF Materials(U)

| Designation | Batch | Atlas Match | M1A1 Squib | Remarks |
|---|---|---|---|---|
| | | Liquids | | |
| NFPA | 117 | NR | NR | |
| TVOPA | 100-IN | E | | |
| GNFPA | | NR | NR | |
| NFPF | 148 | B | B | |
| NFPA/AA/ETAC | -- | NR | NR | |
| NFPA/AA/ETAC | | B | | 20cc of sample remaining |
| OPE/Solvent | B-11 | | NR[a] | 14/86 |
| TVOPA/Solvent | 100-75 | NR | NR | 25/75 |
| TVOPA/Solvent | 100-50 | NR | NR | 50/50 |
| TVOPA/Solvent | 100-15 | NR | NR | 15/85 |
| NFPOH/Solvent | -- | B | B | 77/23 |
| NFPOH/Solvent | | NR | NR | 50/50 |
| NFPF/Solvent | 371-1 | NR | NR | 22/78 |
| PPAA-3/Solvent | 1001 | NR | NR | 16/84 |
| PPAA-3/Solvent | 1001 | NR[b] | NR | 16/84 at reflux |
| PPAA-5/Solvent | 105 | NR | B-80/570[c] | 39/61 |
| TP-11/Solvent | 1001 | NR | NR | 14/86 |

Table IX. (Cont'd) (C) Ignition-Test Results for NF Materials(U)

| Designation | Batch | Atlas Match | M1A1 Squib | Remarks |
|---|---|---|---|---|
| | | Binders | | |
| TP-9 | 1001 | B | | |
| TP-11 | 1003 | B | B | |
| TP-14 | 1000 | B-75/2 | B-75/2 | |
| TP-14 | 1000 | B-41/1 | | 115°F |
| TY-1 | TP-12G-101 | B-90/12 | B-90/12 | |
| TP-GNFPA | MB-669-48 | B | | |
| | | Slurries | | |
| RH-SE-103cd | 1007 | B | | |
| RH-SE-103A | 1049 | B | B | |
| RH-SE-233 | 1003 | B-90/30 | B-90/25 | |
| RH-SE-234ci | 1001 | B-75/8 | B-90/9 | |
| RH-SE-240cc | 7001 | B-75/17 | B-75/15 | |
| TP-11/AP | | B | B | 39/46 |
| TP-11/Al | | B | B | 39/15 |
| TP-11/AP/Al | | B | B | 39/46/15 |

[a] Below surface
[b] 2 in. above surface
[c] Reported as grams of sample to seconds burning time

Table X. (C) Friction-Sensitivity Test Results by Esso Friction Screw(7) for NF Materials(U)

| Designation | Batch | Grit (100 Mesh) None | Glass | SiC | Remarks |
|---|---|---|---|---|---|
| | | Liquids | | | |
| NFPA | 117 | | | 0/5[a] | |
| TVOPA | 100N | | | 0/5 | |
| TVOPA | T-121-1 | 0/5 | 1/5 | 0/5 | |
| TVOPA | T-125-2A | 0/5 | 1/4 | 0/5 | |
| NFIPC | | | 0/1 | 0/2 | |
| NFPF | 148 | | | 0/5 | |
| NFPOH | JW-1097-65 | | | 0/5 | |

Table X. (Cont'd.) (C) Friction-Sensitivity Test Results by Esso Friction Screw(7) for NF Materials (U)

| Designation | Batch | Grit (100 Mesh) None | Glass | SiC | Remarks |
|---|---|---|---|---|---|
| HPE | -- | | | 0/5 | |
| HPE | -- | | | 0/5 | |
| OPE | B-12 | 0/5 | 1/1 | 1/1 | |
| FA-TNENE | -- | 0/1 | | 0/1 | |
| TP-11/Solvent | 1003CS | | | 0/2 | Rapid solvent evaporation |
| PPAA-3 | 1001N | | | 0/5 | Gumstock |
| **Binders** | | | | | |
| TP-11 | 1004 | | | 0/5 | |
| **Slurries** | | | | | |
| RH-SE-103A | 1049 | | 0/2 | 2/3 | |
| RH-Y-1af | 01 | | | 1/3 | Incomplete; machine failed |
| TP-11/AP | | | | 0/5 | 39/46, no curing agent |
| TP-11/Al | | | | 0/1 | 39/15, no curing agent |
| TP-11/AP/Al | | | | 1/5 | 39/46/14, no curing agent |
| **Propellants** | | | | | |
| RH-SE-103A | 1050 | | | 0/5 | |
| RH-Y-1af | 02 | | | 2/5 | |

[a] Reported as the number of positive results to the number of trials.

Table XI. (C) Friction-Sensitivity Test Results by Thiokol Rotating Cup(8) for NF Materials(U)

| Designation | Batch | Result | RPM | Remarks |
|---|---|---|---|---|
| RH-SE-239 | 7002 | -[a] | 7000 | HMX(B)/Al/TP-11 = 59/1/40 |
| RH-SE-240cc | 7001 | + | 6000 | AP/HMX(B)/Al/TP-11 = 20/39/1/40 |
| RH-SE-240ci | 7002 | + | 6000 | |

[a] Limit of test

Table XII. (C) Lead-Column Test Results for NF Materials(U)

| Designation | Batch | Detonator | Result | Remarks |
|---|---|---|---|---|
| | | Liquids | | |
| IBA | -- | No. 8 | "Go" | |
| NFPA | 117 | J-2 | 0.2 | |
| NFPF | 148 | No. 8 | 1.1 | |
| NFPA/AA/Solvent | 117S | J-2 | 0 | 15.2/0.8/84 |
| TVOPA/Solvent | 100-75 | J-2 | 0.7 | 75/25 |
| TVOPA/Solvent | 100-50 | J-2 | 0.06 | 50/50 |
| TVOPA/Solvent | 100-15 | J-2 | 0 | 15/85 |
| NFPOH/Solvent | | J-2 | 0 | 50/50 |
| NFPOH/Solvent | | No. 8 | 1.2 | 77/23 |
| NFPF/Solvent | 371-1 | J-2 | 0 | 22/78 |
| PPAA-3/Solvent | 1001 | J-2 | 0 | 16/84 |
| TP-11/Solvent | 1003CS | J-2 | 0 | 14/86 |
| DFSA/$H_2SO_4$ | -- | No. 8 | 0 | 5.4 molar DFSA in $H_2SO_4$ |
| B-1/Solvent | -- | No. 8 | 0 | 1.8 molar B-1 in Freon 113 |
| | | Binders | | |
| TP-11 | 1003 | J-2 | 0.44 | |

Table XII. (Cont'd) (C) Lead-Column Test Results for NF Materials(U)

| Designation | Batch | Detonator | Result | Remarks |
|---|---|---|---|---|
| | | Slurries | | |
| TP-11/AP | | No. 8 | 1.6 | 39/46 |
| TP-11/Al | | No. 8 | 1.2 | 39/15 |
| TP-11/AP/Al | | No. 8 | 1.7 | 39/46/15 |
| RH-SE-103A | 1049 | No. 8 | 1.7 | 39/46/15 |
| | | Propellants (2 in. cube) | | |
| RH-SE-103A | 1050 | No. 8 | 0 | |
| RH-SE-103A | 1052 | J-2 | 1.4 | |
| RH-SE-103A | 1052 | No. 8 | 0 | |

Table XIII. (U) Bottle-Drop Test Results for NF Materials

| | | Test[a] | | |
|---|---|---|---|---|
| Designation | Batch | 1 | 2 | 3 |
| NFPA | 117 | 0/5[b] | 0/5 | 0/1 |
| NFPF | 148 | 0/5 | 0/5 | 0/1 |
| TVOPA | 100N | 0/5 | 0/5 | 0/1[c] |
| TP-11 | 1003 | 0/5 | 0/5 | 0/1 |
| NFPA/AA/Solvent | 117S | 0/5 | 0/5 | 0/1 |
| PPAA-3/Solvent | 1001 | 0/5 | 0/5 | 0/1 |
| TP-11/Solvent | 1003CS | 0/5 | 0/5 | 0/1 |
| TP-19/Solvent | 101 | 0/1 | | 0/1 |
| TU-105/Solvent | 7001 | 0/3 | | 0/3 |

[a] Test 1: Successive drops of a 25-cc sample contained in a 120-cc polyethylene bottle from a height of 115 in. onto a steel plate.

Test 2: Same as Test 1 with the addition of approximately 50 $\frac{1}{8}$-in.-diam. glass beads.

Test 3: One drop of a 25-cc sample contained in a 38-cc glass vial from a height of 115 in.

[b] Reported as the number of positive results to the number of trials. Any observed exothermic reaction is a positive result.

[c] See Ref. (3) for additional data.

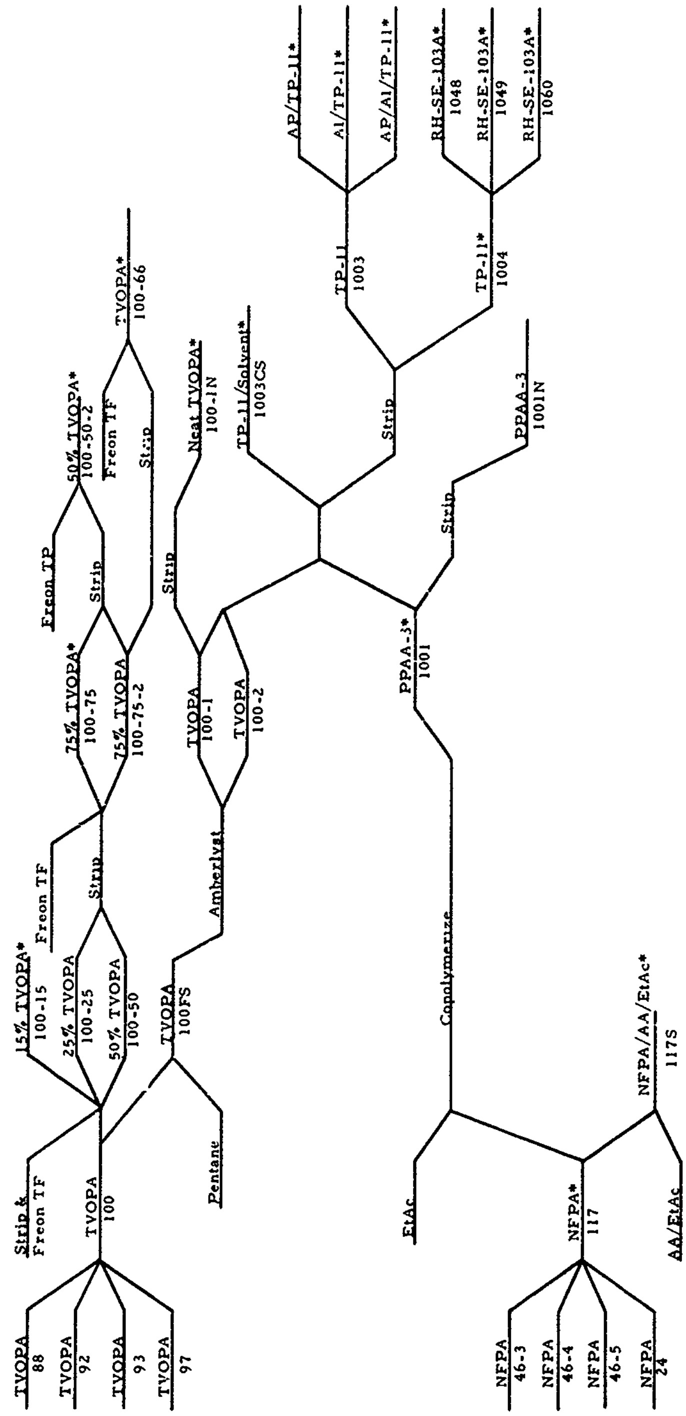


FIGURE 3. (C) BATCH NUMBER FLOW SHEET FOR RH-SE-103A PROCESS SURVEY (U).

# APPENDIX B

## (C) SENSITIVITY DATA FOR NON-NF MATERIALS(U)

(U) Published herewith are the sensitivity data obtained on non-NF materials obtained since the publication of Rohm and Haas Company Special Report S-79 (3). These data were accumulated as a part of the continuing hazards evaluation program at these Laboratories. For completeness, card-gap and failure-diameter data performed for other reasons have been included.

| | |
|---|---|
| Table XIV | Card-Gap-Sensitivity Test Results for non-NF Materials. |
| Table XV | Failure-Diameter Test Results for non-NF Materials. |
| Table XVI | Differential-Thermal-Analysis Test Results for non-NF Materials. |
| Table XVII | Impact-Sensitivity Test Results for non-NF Materials. |
| Table XVIII | Ignition-Sensitivity Test Results for non-NF Materials. |
| Table XIX | Friction-Sensitivity Test Results by Esso Friction Screw for non-NF Materials. |
| Table XX | Friction-Sensitivity Test Results by Thiokol Rotating Cup for non-NF Materials. |
| Table XXI | Lead-Column Test Results for non-NF Materials. |

Table XIV. (C) Card-Gap Sensitivity Test Results for non-NF Materials(U)

Small Scale

| Designation | Batch | Gap Thickness (in.) | Remarks |
|---|---|---|---|
| | | Binders | |
| PAP-1[a] | | $0.12^{1/0}$-$0.15^{0/1}$ | TEGDN/TMETN/[PA/AA= 95/5] = 20/40/40 |
| TZ-1 | 6002 | $0.02^{2/0}$-$0.04^{0/2}$ | TEGDN/TMETN/[PA/AA= 92.5/7.5]= 20/40/40 |
| TZ-3 | 01 | $0.11^{1/0}$-$0.18^{0/1}$ | TEGDN/BTTN/[PA/AA = 92.5/7.5] = 10/50/40 |
| | | Slurries | |
| RH-Z-1 | J-14-04 | $1.58^{2/0}$-$1.60^{0/2}$ | HMX(F)/TZ-1 = 50/50 |
| RH-Z-1 | 6000 | $1.64^{2/1}$-$1.66^{0/2}$ | |
| RH-Z-8 | 6002 | $1.40^{2/0}$-$1.42^{1/2}$ | HMX(B)/TZ-1 = 53/47 |
| RH-Z-13 | 01 | $1.50^{1/0}$-$1.60^{0/1}$ | HMX(B)/TEGDN/BTTN[PA/AA = 92.5/7.5] = 53/5/23/19 |
| RH-Z-19cc | 01 | $1.33^{1/0}$-$1.36^{0/1}$ | AP/HMX(B)/Al/TZ-5 = 26/26/15/33 |
| RH-Z-20cc | 01 | $0.15^{1/0}$-$0.18^{0/1}$ | AP/Al/TZ-5 = 52/15/33 |
| RH-Z-20ci | 02 | $0.55^{1/1}$-$0.58^{0/1}$ | |
| RH-Z-21 | 04 | $1.77^{1/1}$-$1.80^{0/2}$ | RDX(E)/TZ-5 = 53/47 |
| RH-Z-41 | 7001 | $1.46^{1/0}$-$1.48^{0/1}$ | HMX(B)/TZ-3 = 50/50 |
| | | Propellants | |
| RH-B-18 | 1005 | $0.02^{2/0}$-$0.04^{0/2}$ | AP[b]/RDX/Al/PBAA=50/20/10/20 |
| RH-B-23 | 1002 | $D_f$ <0.48 | AP[b]/RDX/Al/PBAA=52.5/16/10.5/21 |
| RH-B-24 | 1001 | $D_f$<0.48 | AP[b]/RDX/Al/PBAA=56.3/10/11.2/22.5 |
| RH-B-25 | 1013 | $1.40^{2/0}$-$1.42^{0/2}$ | AP[b]/RDX/Al/PBAA=51.2/18/10.3/20.5 |
| RH-B-25 | 1014 | $1.47^{2/0}$-$1.49^{0/2}$ | +135°F |
| RH-B-25 | 1014 | $1.44^{2/0}$-$1.47^{0/2}$ | 144, 0.01 in. CA cards. |

Table XIV. (Cont'd) (C) Card-Gap Sensitivity Test Results for non-NF Materials(U)

| Designation | Batch | Gap Thickness (in.) | Remarks |
|---|---|---|---|
| RH-P-112cb | 1772 | $0.74^{2/0}$-$0.76^{0/2}$ | AP/Al/TEGDN/DBP = 30/15/37/17 |
| RH-P-112cf | 1999 | $0.52^{2/0}$-$0.54^{0/2}$ | 53μ Al, 95% range 38μ-62μ |
| RH-P-112cf | 2003 | $0.46^{2/0}$-$0.48^{0/2}$ | 53μ Al, 95% range 38μ-62μ |
| RH-P-427ce | 1000 | $0.48^{2/0}$-$0.50^{0/2}$ | AP/Al/TEGDN/DBP = 43/2/37/17 |
| RH-P-427ce | 1001 | $0.46^{2/0}$-$0.48^{0/2}$ | 53μ Al, 95% range 38μ-62μ |
| RH-P-430ce | 1000 | $0.38^{2/0}$-$0.40^{0/2}$ | AP/TEGDN/DBP=44/38/17 |
| PTA-10[c] | 02 | $1.62^{1/0}$-$1.65^{0/1}$ | HMX(E)/TEGDN/[PA/AA=95/5] = 65/17.5/17.5 |
| PTA-12[c] | 01 | $1.53^{2/0}$-$1.55^{0/1}$ | HMX(E)/TEGDN/[PA/AA=95/5]= 50/25/25 |
| PTA-13[c] | 01 | $1.40^{1/0}$-$1.45^{0/1}$ | HMX(E)/TEGDN/[PP/AA=95/5] = 40/30/30 |
| RH-Z-1 | 6000 | $1.64^{2/0}$-$1.66^{0/2}$ | HMX(F)/TZ-1= 50/50 |
| RH-Z-8 | 6002 | $1.46^{2/0}$-$1.48^{0/2}$ | HMX(B)/TZ-1=53/47 |
| RH-Z-20 | 7001 | $0.46^{2/0}$-$0.48^{0/2}$ | AP/Al/TZ-5 = 51/15/34 |
| RH-Z-21 | 01 | $1.86^{1/0}$-$2.13^{0/1}$ | RDX(E)/TZ-5 = 53/47 |
| RH-Z-41 | 7001 | $1.50^{2/0}$-$1.52^{0/2}$ | HMX(B)/TZ-3 = 50/50 |
| C-4 | | $1.87^{2/0}$-$1.89^{0/2}$ | 91% RDX in synthetic wax |
| | | Large Scale | |
| | | Slurries | |
| RH-X-101cb | 7001 | $0.00^{1/0}$-$0.70^{0/1}$ | AP/Al/TEGDN/[CMA/AA=95/5] = 57/5/15/23 |
| | | Propellants | |
| RH-B-16 | 1004 | $1.22^{2/0}$-$1.24^{0/2}$ | -40°F, AP[a]/RDX/Al/PBAA |
| RH-B-16 | 1004 | $1.39^{2/0}$-$1.41^{0/2}$ | 74°F= 53/15/11/21 |
| RH-B-16 | 1004 | $1.37^{2/0}$-$1.39^{0/2}$ | 160°F |
| RH-B-16 | 1004 | $1.37^{2/0}$-$1.39^{0/2}$ | 200°F |
| RH-B-18 | 1005 | $1.40^{2/0}$-$1.42^{1/2}$ | AP[b]/RDX/Al/PBAA=50/20/10/20 |
| RH-B-23 | 1002 | $1.34^{2/0}$-$1.36^{0/2}$ | AP[b]/RDX/Al/PBAA=52.5/16/10.5/21 |

Table XIV. (Cont'd) (C) Card-Gap Sensitivity Test Results for non-NF Materials(U)

| Designation | Batch | Gap Thickness (in.) | Remarks |
|---|---|---|---|
| RH-B-24 | 1000 | $1.18^{2/0}-1.20^{0/3}$ | AP[b]/RDX/Al/PBAA=56.3/10/11.2/22.5 |
| RH-B-25 | 1013 | $1.40^{2/0}-1.42^{0/2}$ | AP[b]/RDX/Al/PBAA=51.2/18/10.3/20.5 |
| RH-B-25 | 1014 | $1.41^{2/0}-1.43^{0/2}$ | |
| RH-B-25 | 1014 | $1.41^{2/0}-1.43^{0/2}$ | +135°F |
| RH-B-25 | 1014 | $1.40^{2/0}-1.42^{0/2}$ | 138, 0.01 in. CA cards |
| RH-P-112cb | 1721 | $0.68^{2/0}-0.70^{0/2}$ | AP/Al/TEGDN/DBP=30/15/37/17 |
| RH-P-112cb | 1776 | $0.70^{1/0}-0.72^{0/1}$ | Surveillance check, cf 0.70-0.72, 19 mos. |
| RH-P-112cb | 1778 | $0.72^{1/0}-0.74^{0/1}$ | Surveillance check, cf 0.70-0.72, 19 mos. |
| RH-P-112cb | 1849 | $0.68^{2/0}-0.70^{0/2}$ | Pentolite donor L/D = 1 |
| RH-P-112cb | 1849 | $0.86^{1/0}-0.88^{0/1}$ | Pentolite donor L/D = 1.5 |
| RH-P-112cb | 1849 | $0.96^{2/0}-0.98^{0/2}$ | Pentolite donor L/D = 2 |
| RH-P-112cb | 1849 | $1.03^{2/0}-1.05^{0/2}$ | Pentolite donor L/D = 3 |
| RH-P-112cf | 2008 | $0.30^{2/0}-0.32^{0/2}$ | -39°F |
| RH-P-112cf | 2008 | $0.62^{2/0}-0.64^{0/2}$ | 72°F |
| RH-P-112cf | 2008 | $0.75^{2/0}-0.77^{0/2}$ | 140°F |
| RH-P-112cf | 2008 | $0.84^{2/0}-0.86^{0/2}$ | 200°F |
| RH-P-112cc | 2035 | $0.67^{2/0}-0.69^{0/2}$ | |
| RH-P-112ce | 2036 | $0.62^{2/0}-0.64^{0/2}$ | |
| RH-P-197cb | 1014 | $1.24^{2/0}-1.26^{0/2}$ | AP/RDX(A)/Al/TMETN/TEGDN/DBP = 10/29/18/24/8/10, surveillance check, cf 1.20-1.22, 30 mos. |
| RH-P-324 | 1008 | $0.48^{1/0}-0.50^{0/1}$ | Surveillance check, 0.68-0.70, 32 mos. |
| RH-P-324 | 1009 | $0.50^{1/0}-0.52^{0/1}$ | Surveillance check, 0.68-0.70, 32 mos. |
| RH-P-387 | 1000 | $0.66^{1/0}-0.70^{0/1}$ | Surveillance check, 0.74-0.76, 21 mos. |

Table XIV. (Cont'd) (C) Card-Gap Sensitivity Test Results for non-NF Materials(U)

| Designation | Batch | Gap Thickness (in.) | Remarks |
|---|---|---|---|
| M-7 | | $0.64^{2/0}$-$0.66^{0/2}$ | KP/NG/NC/C = 7.8/35.5/ 54.6/1.2 |
| DBP | 14 | $2.50^{2/0}$-$2.70^{0/2}$ | "Fluid Ball"®[d] propellant |
| C-4 | | $2.21^{2/0}$-$2.23^{0/2}$ | 91% RDX in synthetic wax |
| AP cf | 1055 | $1.68^{2/0}$-$1.70^{1/2}$ | |

[a] Experimental TZ- Binder
[b] cc/ce = 70/30. Class E RDX
[c] Experimental RH-Z propellant
[d] Trademark of Olin-Mathieson Chemical Corp., New York, N. Y.

Table XV. (C) Failure-Diameter Test Results for non-NF Materials(U)

Steel Confined

| Designation | Batch | $D_f$,[a] in. | Remarks |
|---|---|---|---|
| | | **Binders** | |
| PAP-1 | | 0.36-0.48 | TEGDN/TMETN/[PA/AA = 95/ 5] = 20/40/40 |
| TX-3 | 101 | >0.48 | |
| TZ-1 | 6002 | 0.36-0.48 | |
| TZ-5 | | >0.48 | |
| | | **Slurries** | |
| RH-C-60 | 107 | >0.48 | AP/Al/DOA/CTPB=68/14/8/10 |
| RH-C-72 | 100 | >0.48 | AP/Al/CTPB=67/15/18 |
| RH-C-72 | 101 | >0.48 | |
| RH-C-84 | 100 | >0.48 | AP/Al/nBF/CTPB=70/1/8/21 |
| RH-Z-1 | J-14-04 | <0.27 | HMX(F)/TZ-1 = 50/50 |
| RH-Z-1 | 6000 | <0.27 | |
| RH-Z-8 | 6002 | <0.27 | HMX(B)/TZ-1 = 53/47 |

Table XV. (Cont'd) (C) Failure-Diameter Test Results for non-NF Materials(U)

| Designation | Batch | $D_f$,[a] in. | Remarks |
|---|---|---|---|
| RH-Z-21 | 04 | <0.36 | HMX(B)/TZ-6 = 53/47 |
| C-686-15 | | >0.48 | AP[b]/Al/ZL-434/nBF=60/20/10/10 |
| C-686-16 | | >0.48 | AP[b]/Al/ZL-434/nBC = 60/20/10/10 |
| C-686-17 | | >0.48 | AP[b]/Al/ZL-434/DOA = 60/20/10/10 |
| C-686-19 | | >0.48 | AP[b]/Al/ZL-434/NFIPC = 60/20/10/10 |

Propellants

| Designation | Batch | $D_f$,[a] in. | Remarks |
|---|---|---|---|
| RH-P-112cf | 1999 | 0.36-0.48 | AP/Al/TEGDN/DBP = 30/15/37/17 |
| RH-P-427ce | 1000 | <0.27 | AP/Al/TEGDN/DBP = 43/2/37/17 |
| RH-P-430ce | 1000 | 0.27-0.36 | AP/TEGDN/DBP = 44/38/17 |
| RH-Z-1 | 6000 | <0.27 | HMX(F)/TZ-1 = 50/50 |
| RH-Z-8 | 6002 | <0.27 | HMX(B)/TZ-1 = 53/47 |

Cardboard Confined

| Designation | Batch | $D_o$, in.[a] | $D_f$,in.[a] | $D_i$,in.[a] | Remarks |
|---|---|---|---|---|---|
| RH-B-16 | 1001 | 1.4-1.5 | | | |
| RH-B-16 | 1002 | >1.5 | | | 1 pentolite pellet donor |
| RH-B-16 | 1002 | | | 0.82-1.0 | 2.5 in. acceptors |
| RH-B-16 | 1002 | | >1.5 | | C-4 donor |
| RH-B-16 | 1004 | 1.4-1.5 | | | -40°F |
| RH-B-16 | 1004 | 1.4-1.5 | | | 74°F |
| RH-B-16 | 1004 | 1.4-1.5 | | | 160°F |
| RH-B-16 | 1004 | 1.5-1.6 | | | 200°F |
| RH-B-24 | 1002 | | >3.0 | | C-4 donor |
| RH-B-24 | 1002 | | >3.0 | | C-4 donor, conical |
| RH-B-24 | 1003 | | | 2.2-2.5 | 4.0 in. acceptors |
| RH-B-24 | 1003 | | | >2.2 | 4.0 in. acceptors |
| RH-B-24 | 1004 | | | <1.61 | 3.25 in. acceptors |

Table XV. (Cont'd) (C) Failure-Diameter Test Results for non-NF Materials(U)

| Designation | Batch | $D_o$,in.[a] | $D_f$,in.[a] | $D_i$,in.[a] | Remarks |
|---|---|---|---|---|---|
| RH-B-24 | 1005 | | >3.5 | | C-4 donor |
| RH-B-24 | 1006 | | | 2.0-2.3 | 3.75 in. acceptors |
| RH-B-24 | 1007 | | | 2.2-2.5 | 3.75 in. acceptors |
| RH-B-25 | 1010 | 1.0-1.5 | | | 2 pentolite pellet |
| RH-B-25 | 1011 | | 2.0-2.5 | | |
| RH-B-25 | 1012 | 1.0-1.2 | | | 1 pentolite pellet |
| RH-B-27 | 1000 | | 2.2-2.5 | | |
| RH-B-27 | 1001 | | | 1.4-1.5 | 2.5 in. acceptors |
| RH-B-27 | 1001 | | | 1.4-1.5 | 3.0 in. acceptors |
| RH-P-112cb | 1841 | 0.9-1.0 | | | |
| RH-P-112cb | 1861 | | | 0.8-1.0 | 2.0 in. acceptors |
| RH-P-112cf | 1999 | >1.38 | | | 53μ Al |
| RH-P-112cf | 2003 | | | 1.4-1.5 | 1.8 in. acceptors |
| RH P-112cf | 2003 | 1.6-1.8 | | | 53μ Al |
| RH-P-112cf | 2008 | 0.82-1.0 | | | 72°F, 2 pentolite pellets |
| RH-P-112cf | 2008 | | | 0.82-1.0 | 72°F, 1.05 in. acceptors. |
| RH-P-112cf | 2008 | 0.82-1.0 | | | 140°F, 2 pentolite pellets |
| RH-P-112cf | 2008 | | | 0.62-0.75 | 140°F, 1.05 in. acceptors |
| RH-P-112cf | 2008 | 1.2-1.4 | | | -39°F, 2 pentolite pellets |
| RH-P-112cf | 2008 | | | 1.1-1.2 | -39°F, 1.4 in. acceptor |
| RH-P-112cf | 2008 | 0.62-0.75 | | | 200°F, 2 pentolite pellets |
| RH-P-112cf | 2008 | | | 0.50-0.62 | 200°F, 0.75 in. acceptor |
| RH-P-112cf | 2008 | 0.82-1.0 | | | 72°F, 2 pentolite pellets |
| RH-P-112cf | 2008 | | | 0.75-0.82 | 72°F, 1.05 in. acceptor |
| RH-P-181cb | 1006 | | | 1.2-1.4 | 3 in. acceptor |
| RH-P-181cb | 1006 | | | <1.15 | 2.5 in. acceptor |
| RH-P-181cb | 1007 | | >2.0 | | 1 pentolite pellet |
| RH-P-181cb | 1007 | | 1.9-2.0 | | C-4 donors |
| RH-P-181cb | 1007 | | | 1.4-1.5 | 3.0 in. acceptors |
| RH-P-181cb | 1007 | | | 1.1-1.3 | 2.5 in. acceptors |
| RH-P-181cb | 1007 | | | 1.1-1.3 | 1.75 in. acceptors |

Table XV. (Cont'd) (C) Failure-Diameter Test Results for non-NF Materials(U)

| Designation | Batch | $D_o$, in.[a] | $D_f$, in.[a] | $D_i$, in.[a] | Remarks |
|---|---|---|---|---|---|
| RH-P-184cb | 1006 | 1.4-1.5 | | | |
| RH-P-184cb | 1006 | | | <1.15 | 2.5 in. acceptors |
| RH-P-184cb | 1007 | | | 1.1-1.3 | 2.5 in. acceptors |
| RH-P-184cb | 1007 | | | 1.1-1.3 | 1.75 in. acceptors |
| RH-P-387cb | 1001 | 0.82-1.0 | | | |
| RH-P-388cb | 1001 | 1.1-1.2 | | | |
| RH-P-427ce | 1000 | <1.0 | | | |
| RH-P-427ce | 1000 | | | 0.62-0.82 | 1.05 in. acceptors |
| RH-P-427ce | 1000 | >0.84 | | | wafer technique |
| RH-P-427ce | 1001 | 1.2-1.4 | | | |
| RH-P-430ce | 1000 | 1.1-1.3 | | | |
| RH-P-430ce | 1000 | | | 1.0-1.1 | 1.3 in. acceptors |

[a] $D_o$: overboosted, donor diam. > acceptor diam.
$D_f$: donor diam. = acceptor diam.
$D_i$: inverse method (13), donor diam < acceptor diam.
[b] cc/ce = 50/50

Table XVI. (U) Differential-Thermal Analysis Results non-NF Materials

| Designation | Batch | Peak Exotherm, °C |
|---|---|---|
| | Copolymers | |
| PZ-1 | 6004 | 215 |
| PZ-1 | 7002 | 208 |
| PZ-101 | 7001 | 216 |
| | Binders | |
| TZ-1 | | 191-197 range of values<br>204-207 for double peak |
| TZ-6 | | 183 |
| TZ-8 | | 206 |
| TZ-9 | | 206 |
| TZ-101 | | >360 |

Table XVI. (Cont'd) (U) Differential-Thermal Analysis Results for non-NF Materials

| Designation | Batch | Peak Exotherm, °C |
|---|---|---|
| **Propellants** | | |
| RH-Z-41 | 7001 | 185 |
| **Liquids** | | |
| NG | | 204 |

Table XVII. (C) Impact-Sensitivity Test Results for non-NF Materials(U)

| Designation | Batch | Picatinny Kg-in. | Remarks |
|---|---|---|---|
| **Liquids** | | | |
| NG | | 7.86 | |
| NG/EG | | 24.8 | 75/25 |
| PZ-101/Solvent | 7001 | >38 | 27/73 |
| **Binders** | | | |
| TZ-2 | 7001 | 16.1 | TEGDN/BTTN/PZ-1 = 20/40/40 |
| TZ-9 | 7001 | >38 | TEGDN/BTTN/PZ-1 = 40/20/40 |
| TZ-101 | 7001 | 7.7 | TEGDN/TMETN/PZ-101 = 20/40/40 |
| **Propellants** | | | |
| RH-X-101ce | 7003 | 7.7 | AP/Al/TX-1 = 57/5/38 |
| RH-Z-8 | 6002 | 14.0 | HMX(B)/TZ-1 = 53/47 |
| RH-Z-32cc | 7001 | 4.1 | APC/Al/TZ-5 = 52/15/33 |
| RH-Z-32ce | 7004 | 5.8 | |
| RH-Z-41 | 7001 | >38 | HMX(B)/TZ-3 = 50/50 |
| **Powders** | | | |
| AP | 1055 | 14.4 | cf grind |
| DBP | 14 | 10.6 | "Fluid Ball" |
| RDX | | 10.5 | Recrystallized |

Table XVIII. (U) Ignition-Test Results for non-NF Materials and Reference Liquids

| Designation | Batch | Atlas Match | M1A1 Squib | Remarks |
|---|---|---|---|---|
| | | **Binders** | | |
| TU-105 | 7002 | B-45/15[a] | | |
| TU-105 | 7002 | B-45/1 | | 180°F |
| TZ-1 | 6002 | NR | NR | |
| | | **Slurries** | | |
| RH-C-60 | 107 | B | B | |
| RH-C-72 | 100 | B | B | |
| RH-C-72 | 101 | B | B | |
| RH-C-84 | 100 | B | B | |
| RH-C-135 | 102 | B | B | |
| RH-U-105 | 7002 | B-75/12 | | |
| RH-X-101 | 7001 | B-75/9 | B-75/9 | |
| RH-Z-1 | 6000 | NR | NR | |
| RH-Z-8 | 6002 | NR | B-100/130 | |
| RH-Z-41 | 7001 | NR | NR | |
| C-686-15 | -- | B | B | |
| C-686-16 | -- | B | NR | |
| C-686-17 | -- | NR | NR | |
| | | **Reference Liquids** | | |
| Ethyl Acetate | | | NR | 2 in. above surface |
| Gasoline | | | NR | Burned, 2 in. above surface |
| Glycerine | | | NR | 177°F |
| Methyl Alcohol | | | B | Burned, 1/4 in. above surface |
| Nitroglycerin | | NR | NR | NR above surface |
| TEGDN | PL-11 | NR | NR | |
| TMETN | CL-6 | NR | NR | |

[a]Reported as grams in sample to seconds burning time.

Table XIX. (U) Friction-Sensitivity Test Results by Esso Friction Screw (7) for non-NF Materials

| Designation | Batch | Grit (100 mesh) None | Glass | SiC |
|---|---|---|---|---|
| **Solids** | | | | |
| Match Heads | -- | 5/5[a] | | 2/2 |
| HMX - Class A | | | | 0/1 |
| HMX - Class E | | | | 0/2 |
| HMX - Class D | | | | 0/2 |
| HMX - Alpha | | | | 0/5 |
| HMX - Beta | | | | 0/5 |
| HMX - Gamma | | | | 0/5 |
| **Liquids** | | | | |
| TMETN | CL-6 | | | 0/5 |
| NG | | | | 0/5 |
| **Slurries** | | | | |
| RH-P-112cf | 1955 | | 0/5 | 1/4 |
| RH-P-425ci | 01 | | | 0/5 |
| **Propellants** | | | | |
| RH-C-60 | 106 | | | 0/5 |
| RH-C-78 | 1001 | | | 0/5 |
| RH-C-135 | -- | | | 0/5 |

[a]Reported as number of positive results to the number of trials.

Table XX. (C) Friction-Sensitivity Test Results by Thiokol Rotating Cup (8) for non-NF Materials(U)

| Designation | Batch | Result | At RPM | Remarks |
|---|---|---|---|---|
| RH-X-101cb | 7001 | + | 2800 | AP/Al/TX-1=57/5/38 |
| RH-X-101ce | 7003 | + | 1800 | |
| RH-X-101 cb/ci | 7002 | + | 2800 | cb/ci = 80/20 |
| RH-Z-1 | 6001 | -[a] | 7000 | HMX(F)/TZ-1 = 50/50 |
| RH-Z-32cc | 7001 | + | 6000 | AP/Al/TZ-5=52/15/33 |
| RH-Z-32ci | 7003 | - | 7000 | |

[a]Limit of test

Table XXI. (U) Lead-Column Test Results for non-NF Materials

| Designation | Batch | Detonator | Result | Remarks |
|---|---|---|---|---|
| | | Solids | | |
| C-4 | | No. 8 | 1.9 | 2-in. X 2-in. cube, $\rho$ 1.59 gm/cc |
| C-4 | | J-2 | 2.4 | 8 oz. bottle, $\rho$ = 1.59 gm/cc |
| DBP | 14-I | J-2 | 2.0 | 1-in. -diam. cylinder L/D=1 |
| | | Liquids | | |
| NG/EG | | No. 8 | 1.0 | 75/25 |
| NG/EG | | No. 8 | 0.8 | 75/25 |
| NG/EG | | No. 8 | 0.9 | 75/25 |
| NG/EG | | No. 8 | 1.1 | 50/50 |
| NG/EG | | No. 8 | 0.9 | 25/75 |
| TMETN | CL-6 | No. 8 | 1.7 | |
| TEGDN | P-10 | No. 8 | 0 | |
| TEGDN | P-11 | No. 8 | 0 | |
| $H_2O$ | | J-2 | 0 | Blank |

Slurries

The following propellant slurries yielded a "no-go" when tested with a No. 8 detonator: RH-C-60-107, RH-C-72-100, RH-C-72-100, RH-C-84-100, RH-C-135-102.

Table XXI. (U) Lead-Column Test Results for non-NF Materials

| Designation | Batch | Detonator | Result | Remarks |
|---|---|---|---|---|
| | | Propellants 2-in. cube | | |
| RH-Z-1 | 6002 | Atlas Match | 0 | |

The following propellants yielded a "no-go" when tested with a J-2 detonator: RH-P-324 batches[a] 1000, 1001, 1002, 1003, 1005, 1006, 1007, 1008, 1009, 1012, 1013, 1014, RH-P-325, and EYW-24067.

[a]See Ref (14) for RH-P-324 and RH-P-325 compositions.

# APPENDIX C

## (C) COPOLYMER AND BINDER FORMULATIONS

### Copolymer Formulations

| Code | Monomer | Wt. % | | | | Ratio |
|---|---|---|---|---|---|---|
| | | Monomer | AA | EtAC | BPO | Monomer/AA |
| PPAA-1 | NFPA | 14.71 | 0.94 | 84.19 | 0.16 | 94/6 |
| PPAA-2 | NFPA | 15.02 | 0.63 | 84.19 | 0.16 | 96/4 |
| PPAA-3 | NFPA | 14.86 | 0.78 | 84.19 | 0.16 | 95/5 |
| PPAA-4 | NFPA | 23.08 | 0.96 | 75.72 | 0.24 | 96/4 |
| PPAA-5[a] | NFPA | 37.0[a] | 1.6[a] | 61.3 | 0.1 | 96/4 |
| PU-101 | MU | 19.0 | 1.0 | 79.9 | 0.1 | 95/5 |
| PU-103 | MU | 23.7 | 1.2 | 75.0 | 0.1 | 95.2/4.8 |
| PY-1 | MY | 23.08 | 0.96 | 75.72 | 0.24 | 96/4 |
| PZ-1 | MZ | 24.7 | 2.0 | 73.0 | 0.3 | 92.5/7.5 |
| PZ-101 | MZ | 25.4 | 1.3 | 73.0 | 0.3 | 95/5 |

### Binder Formulations

| Code | Plasticizer/Copolymer Ratio |
|---|---|
| TP-9 | TVOPA/PPAA-1 = 2/1 |
| TP-10 | TVOPA/PPAA-2 = 2/1 |
| TP-11 | TVOPA/PPAA-3 = 2/1 |
| TP-12 | TVOPA/PPAA-4 = 2/1 |
| TP-14 | TVOPA/PPAA-3 = 3/1 |
| TP-19[a] | TVOPA/PPAA-5[a] = 2/1 |
| TP-GNFPA[b] | TVOPA/ GNFPA[b]/AA = 95/5 = 2/1 |
| TU-102 | TVOPA/PU-101 = 80/20 |
| TU-105 | TVOPA/PU=103 = 83.5/16.5 |
| TX-1 | TEGDN/ CMA/AA = 95/5 = 40/60 |
| TY-1 | TVOPA/PY-1 = 66.7/33.3 |
| TZ-1 | TEGDN/TMETN/PZ-1 = 20/40/40 |
| TZ-2 | TEGDN/BTTN/PZ-1 = 20/40/40 |
| TZ-3 | TEGDN/BTTN/PZ-1 = 10/50/40 |
| TZ-5 | TEGDN/TMETN/PZ-1 = 33.3/33.3/33.3 |
| TZ-6 | TEGDN/PZ-1 = 60/40 |
| TZ-9 | TEGDN/BTTN/PZ-1 = 40/20/40 |
| TZ-101 | TEGDN/TMETN/PZ-101 = 20/40/40 |

[a] Incremental addition of NFPA and AA

[b] Temporary designation

# (C) GLOSSARY

| | |
|---|---|
| AA | Acrylic acid |
| Al | Aluminum, (Alcoa 140 unless otherwise specified) |
| Alon C® | Aluminum oxide, Trademark of Cabot Corporation, Boston, Massachusetts. |
| AP | Ammonium perchlorate |

The ammonium perchlorate used in the manufacture of a propellant is designated in code form as a two-letter subscript following the numerical code for the propellant formulation. The first letter of the code designates the coating and the second letter the particle size. The coating letter "a" denotes Alon C coating and the coating letter "c" denotes a TCP coating. The particle-size letter denotes the nominal particle size of the ammonium perchlorate as given in the following table with the "c" coating letter as an example

| Designation | Nominal Size, μ |
|---|---|
| cc | 180 |
| ca | 75 |
| cf | 55 |
| cb | 45 |
| cd | 35 |
| ce | 15 |
| ci | 5 |

| | |
|---|---|
| APA | 2, 3-bis(difluoramino)propyl propionate |
| B-1 | 2, 2-bis(difluoramino)propyl trifluoracetate |
| BA | n-butyl acrylate |
| BPO | Benzoyl peroxide |
| BTTN | 1, 2, 4-butanetriol trinitrate |
| C | Carbon |

| | |
|---|---|
| C-4 | Composition C-4, 91% RDX in synthetic wax |
| CA | Cellulose acetate |
| -carborane | Generic name for compounds containing a $C_2H_{11}B_{10}$ group. |
| CMA | Carboranylmethyl acrylate, see MX |
| CTPB | Carboxyl-terminated polybutadiene; ZL-434/MAPO/ERLA = 95.16/3.56/1.28; ZL-434 = CTPB polymer (Thiokol Chemical Corp.); MAPO = tris [1-(2-methyl) aziridinyl] -phosphine oxide (Interchemical Corp.); ERLA = trifunctional epoxide resin (Union Carbide). |
| DBP | Double-base powder. "Fluid Ball"® Olin Mathieson Chemical Corp., New York, N.Y. |
| DFA | Difluoramine |
| DFSA | Difluorosulfamic acid |
| DFU | Difluorourea |
| DOA | Dioctyl adipate |
| DTA | Differential thermal analysis |
| EA | Ethyl acrylate, see MV |
| EG | Ethylene glycol |
| EtAc | Ethyl acetate |
| FA-TNENE | 1,1,1-tris(difluoramino)-5,7,7,7-tetranitro-2-oxa-5-azaheptane (Esso) |
| FeAA | Ferric acetylacetonate |
| Freon®113 | Trademark for a line of fluorocarbon produces |
| Freon TF | (E. I. du Pont de Nemours & Co., Wilmington, Del.). |
| GenesolvD® | Trademark for ultrapure solvents of the halogenated hydrocarbons of the methane and ethane series (Allied Chemical Corp., New York, N.Y. |

| | |
|---|---|
| GNFPA | gem-NFPA, see MY |
| HMX | Octahydro-1, 3, 5, 7-tetranitro-1, 3, 5, 7-tetrazocine classes (15) given in parentheses in formulations. |
| HPE | 1, 2, 3, 5, 6, 7-hexakis(difluoramino)-4-oxaheptane (Esso) |
| HPMA | 3-hydroxypropyl methacrylate |
| IBA | 1, 2-bis(difluoramino)-2-methylpropane |
| KP | Potassium perchlorate |
| MV | Ethyl acrylate (also designated EA) |
| MX | Carboranyl methyl acrylate (also designated CMA) |
| MY | 2, 2-bis(difluoramino)propyl acrylate (also designated GNFPA). |
| MZ | Trinitroxypentaerthritol Acrylate, (also designated PA) |
| nBF | n-butylferrocene |
| nBC | n-butylcarborane |
| NC | Nitrocellulose |
| NFIPC | $N_2F_4$ adduct of isopropenylcarborane |
| NFPA | 2, 3-bis(difluoramino)propyl acrylate |
| NFPF | 2, 3-bis(difluoramino)propyl formate |
| NFPOH | 2, 3-bis(difluoramino)-1-propanol |
| NG | Nitroglycerin |
| OPE | 1, 2, 2, 5, 6, 9, 9, 10-octakis(difluoramino)-4, 7-dioxadecane |
| PA | Petrin acrylate, see MZ |
| PAP | Experimental petrin acrylate binder |

| | |
|---|---|
| PBAA | Polybutadiene-acrylic acid copolymer, PBAA/ERL 2774 = 89.5/10.5 [ERL 2774 = epoxy resin (Union Carbide)] |
| P-BEP | A prepolymer of bis(difluoramino)propylene oxide (Shell Oil Co.) |
| PFG | Perfluoroguanidine |
| PPAA-3 | Copolymer, NFPA/AA = 95/5; When given in designation column of tables it is taken to denote the gumstock rather than the copolymer solution given in Appendix C. |
| RDX | Hexahydro-1, 3, 5-trinitro-s-triazine. Classes (15) given in parentheses in formulations. |
| TCP | Tricalcium phosphate |
| TEGDN | Triethylene glycol dinitrate |
| TMETN | 1, 1, 1-trimethylolethane trinitrate |
| TVOP | 1, 2, 3-tris(vinyloxy)propane |
| TVOPA | 1, 2, 3. tris [1, 2-bis(difluoramino)ethoxy] propane |
| Unox® 221 | Difunctional epoxide, Union Carbide Corp. |
| ZL-434 | CTPB polymer, Thiokol Chemical Corp. |